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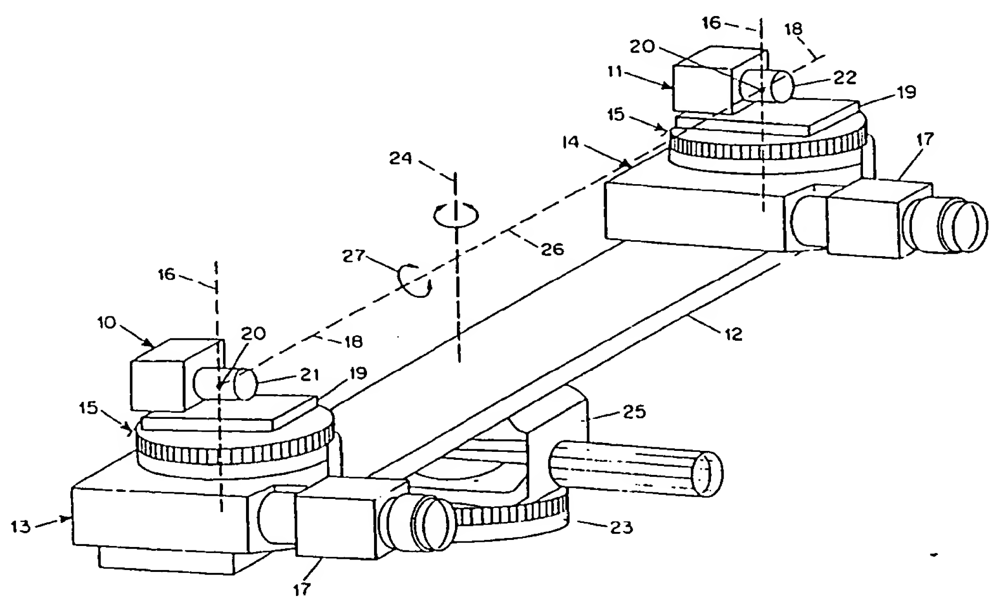

(57) Abstract

An automated stereoscopic image acquisition system acquires image mosaics suitable for photogrammetric analysis by providing an indexing arrangement for rotating at least one camera about the principal node of the camera lens, thereby minimizing image distortion.

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Description

Automated Stereoscopic Image Acquisition and Storage System

Background of the Invention

The present invention relates to a stereoscopic image acquisition and storage system for acquiring an image mosaic suitable for photogrammetric analysis.

The production of stereoscopic images is well known in the art and usually involves the use of two cameras which record the same scene from different perspectives. Conventionally, such images have been obtained by mounting two cameras on a bar with a fixed separation between them, the cameras being angled slightly toward each other to acquire overlapping images. The bar is rotated by hand and, as needed, the angles of the cameras with respect to each other are changed manually in order to converge to a greater or lesser degree for closer or more remote subjects. However, such handheld systems are not useful for preparing mosaics where precise control of image overlap is required. For example, within the camera convergence area it may be desirable to trace a polyhedron, i.e., a series of flat surfaces tangent to the radii of a sphere. In some cases, the bar is rotated automatically and the picture-taking is timed to produce a series of still-frame images of the scene. Typically such systems still suffer from image distortion. Moreover, when a mosaic is prepared, the exposure of various image segments differs somewhat, causing an undesirable variation in the composite.

In addition, such systems do not provide for automated control of camera exposure time. The cameras are often fitted with exposure meters which control the

exposure time as a function of the light levels and the sensitivity of the image recording medium. The exposure time is adjusted in accordance to the average amount of light falling on the area of interest. Thus, it is not possible to acquire several images of a given scene with different exposure times automatically adjusted to shadows or glare.

Finally, annotation of images using such systems is very limited, i.e., usually restricted to frame numbers within a roll of film or a video tape. Thus, careful external records must be maintained in order to keep track of where, and when, the images were acquired.

The Kennedy Patent No. 4,431,290 discloses a portable photogrammetry system using two cameras mounted at opposite ends of a handheld bar and corresponding flash units which are actuated simultaneously to assure that the images recorded by the cameras are taken at the same time. In this case, the cameras are fixed on the bar with their lens axes parallel and cannot be rotated toward or away from each other and the camera bar must be moved manually in horizontal and vertical planes to obtain a mosaic of overlapping images.

The Hines Patent No. 4,650,305 discloses a camera mounting apparatus in which one of two cameras mounted on a support plate is angularly adjustable to change the convergence between the camera axes. The nodal point of the lens for the adjustable camera is placed on a line joining two pivot posts by which the camera support plate is linked to a pair of individually adjustable sliders. The pivoting motion of the camera takes place about another point which is movable in a slot spaced from a line on which the nodal point is disposed.

The Nardate et al. Patent No. 5,084,763 discloses a system for obtaining and handling stereoscopic video signals, but does not disclose any support arrangement providing relative motion for two cameras by which video signals are obtained.

The Barker Patent No. 3,608,457 and Mandler Patent No. 3,731,607 disclose stereoscopic camera arrangements in which a single camera is moved to successive lateral positions along a support bar to obtain stereoscopic images. In both of these patents, the camera is pivoted about a point corresponding to the location of the object being photographed.

Summary of the Invention

Accordingly, it is an object of the present invention to provide an automated stereoscopic image acquisition and storage system which overcomes the above-mentioned disadvantages of the prior art.

It is another object of the present invention to provide an automated stereoscopic image acquisition and storage system which minimizes image distortion and allows precise control of image mosaic geometry.

These and other objects of the invention are attained by providing an automated stereoscopic image acquisition and storage system including a camera mounted for rotation about the principal node of the camera lens. Preferably the system includes a control arrangement for orientation of the camera for all images of an object being photographed, and desirably, it also uses an image intensity histogram for determining the number of photographs of varying exposure to be taken to assure reproduction of all aspects of the object being photographed. Preferably the system includes a pair of identical cameras mounted in spaced relation on a camera support arrangement,

along with an indexing assembly for each of the cameras and for the camera support arrangement.

Brief Description of the Drawings

Further objects and advantages of the present invention will be more fully appreciated from a reading of the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a perspective pictorial view illustrating a typical embodiment of a camera support and control arrangement in accordance with the invention;

Fig. 2 is an enlarged side view showing a representative camera positioning structure for use in the arrangement shown in Fig. 1;

Fig. 3 is a schematic block diagram illustrating a typical embodiment of a stereoscopic image acquisition storage control system in accordance with the invention; and

Fig. 4 is a schematic block diagram showing the details of another representative system controller for use in the invention.

Detailed Description of Preferred Embodiments

In the representative embodiment of the invention shown in Fig. 1, a stereoscopic imaging apparatus includes two identical still frame digital video cameras 10 and 11 supported in spaced relation on a support bar 12 by corresponding indexing head assemblies 13 and 14. Each indexing head rotating assembly has one rotational stage 15 for rotating the supported camera through an azimuthal angle about a vertical axis 16 and another rotational stage 17 for rotating the camera about a horizontal axis 18. If desired, each camera can be rotated independently. Each camera is positioned on a mounting plate 19 so

that both of the axes 16 and 18 pass through the principal node 20 of the camera lenses 21 and 22, respectively. The indexing head assemblies 13 and 14 may incorporate conventional commercially available equipment which permits computer control and resolution to one thousandth of a degree so as to meet image accuracy requirements for less computationally intensive photogrammetric analysis.

The cameras 10 and 11 are provided with positive locking aperture control and focussing systems so that both cameras can be set at identical focus and exposure conditions. Preferably, the camera lenses 21 and 22 are selected such that one camera pixel corresponds to 0.03 inch square or less at a distance of six feet from the camera in object space. Camera lenses suitable for photogrammetric analysis include metric or fixed focus lenses. Alternatively, a variable focus lens locked into a fixed position may also be used. In this case the same clamping device that locks the focus typically also locks the lens aperture setting. The focal length of each variable focus lens is fixed for a particular image acquisition activity. In order to satisfy depth of field requirements, the camera lens aperture is typically closed down to f/11 or f/16. The focal lengths and apertures of both cameras are fixed at the same values for each series of images, thus the same depth of field and field width are obtained in all of the images facilitating photogrammetric analysis. Suitable cameras for photogrammetric analysis include Videk cameras available from Eastman Kodak Corporation in Rochester, New York fitted with Nikon lenses.

An enlarged side view of the camera indexing arrangement is illustrated in Fig. 2. The camera support bar 12 is mounted on a motorized rotational stage 23 arranged to rotate the camera bar through an azimuthal angle about a vertical axis 24 passing

through the center of the bar. A motorized goniometric cradle 25 mounted on the rotational stage 23 is arranged to move the camera bar about a horizontal axis 26 (Fig. 1) which passes through the principal node 20 of the camera by tilting the camera bar 12 about the axis 26 through an angle 27 of up to sixty degrees as shown in Fig. 1. Except for the azimuthal rotation of the bar 12, all movement of the camera bar and thus of the cameras, occurs about the principal node. If necessary, a slide plate (not shown) can be disposed in between the camera mounting plate 19 and the camera rotational stage 15 for alignment of the camera so as to more precisely locate the principal node 17 of the lens at the center of rotation.

The camera bar indexing arrangement is attached to a tripod (not shown) through a tripod mounting plate 28. The tripod should be capable of rigidly holding the camera bar, indexing head assembly, and flood lights or strobe lights and should also have hand-leveling capability and be adjustable in height.

As shown by the system control diagram illustrated in Fig. 3, indexing equipment 30, such as the indexing arrangements 13, 14, 23 and 25 shown in Fig. 1, mechanically linked to the cameras 10 and 11 is arranged to control the orientation of both cameras for appropriate stereo image capture as directed by a system controller 31. The system controller 31 also controls the camera exposure time by actuating mechanical or electronic shutters in the camera. In addition, for fixed lens systems having a variable aperture, the lens apertures are also set by the system controller. Synchronization for strobe lights mounted on the cameras (not shown) is also provided by the system controller.

The system controller 31 includes a portable computer 32 containing a conventional microprocessor,

preferably comprising an Intel 386 CPU available from Intel Corporation, California arranged in a conventional manner to control an image frame grabber 33, a digital tape storage device 34, and a temporary storage device 35, all controlled by input signals from an operator station 36. These components can be assembled into a single package used by an operator to control the system. The operator station 36 includes a video monitor 37 which receives images from the frame grabber 33 to monitor camera image quality, and a computer monitor and keyboard station 38 with a standard keyboard.

The frame grabber 33, which is internal to the system controller, simultaneously obtains and temporarily stores images from each of the cameras 10 and 11, thereafter sending them sequentially to the digital data storage device 34. A suitable frame grabber is available from Matrox Corporation in Dorval, Quebec, Canada.

The digital data storage device 34 in the system controller 31, which collects, catalogs and stores image data, may be a tape, CD ROM or any other suitable device for storing the image data for subsequent photogrammetric analysis. An administrative header for each image including location, camera position data, date and time, exposure time, focal length, and any other desired annotations can be entered on the tape via the keyboard unit 38.

A typical embodiment of a system controller is shown in detail in the block diagram of Fig. 4. In that illustration, an operator station 40 includes a keyboard 41, a computer monitor 42, and a video monitor 43 arranged to receive images from the two cameras 10 and 11 selectively through a video selector switch 44 and corresponding frame grabbers 45 and 46. In addition, a motion controller 47 and a motor driver 48

supply appropriate signals to the indexing head assemblies shown in Fig. 1. The motion controller and motor driver are of the type available from Newport/Klinger Corporation.

The typical control system shown in Fig. 4 also includes separate mass memory devices controllers 49 and 50 for supplying appropriate camera image signals to corresponding digital tape recording devices 51 and 52 as well as a disk controller 53 communicating with a hard disk device 54 and a floppy disk device 55, all under the control of a computer 56.

Although an operator manually initializes the camera positions, the entire stereoscopic imaging apparatus is automatically controlled by the computer 56, as illustrated in Fig. 4. The computer 56, through the motion controller 47 and motor driver 48, directs the movement of the indexing head assemblies to generate data in accordance with the type of photogrammetric analysis that is to be performed. An image intensity histogram, calculated by computer, is used to determine the number of images to be acquired at differing exposures in a given direction in order to elicit details that may otherwise be hidden in shadows and glare. The number of images and exposure time can be set manually by the operator, or automatically by the computer, based on the histogram values of the reflected light from one or more objects of interest.

The computer collects the obtained images from each camera 10 and 11 through the frame grabbers 45 and 46. In this manner, a sequence of stereo images with known convergence angles and specified image overlap is obtained. In addition, the image from either of the two frame grabbers is selected by the video selector selector switch 44 and displayed on the video monitor 43. The video monitor display thus provides real time

visual confirmation of correct camera location and exposure to the operator.

The computer 56 stitches together or combines the images collected from each frame grabber 45 and 46 to form a composite left and right image and directs the composite images through the memory device controllers 49 and 50 connected to the digital tape devices 51 and 52. The computer 56 also supplies information to and receives information from two disks, the hard disk 54 and the floppy disk 55 via the disk controller 53.

In an alternate embodiment (not shown), a single camera is mounted on a translation stage which in turn is mounted onto the camera bar 12. Under computer control the camera is then moved from one end of the bar 12 to the other, and is pivoted at specified angles about the lens nodal point. In this manner a single camera may provide data usually obtained by two separate cameras. Of course, the time required to acquire the desired imagery in this manner is at least twice as long as when two separate cameras are used. In addition, use of a single camera may result in a loss in precision since the camera takes pictures at different times with different weight distributions on the camera bar. Nevertheless, the use of such a stereoscopic imaging apparatus results in a reduction in cost, not only due to the use of a single camera but also a reduction of associated control equipment.

In a second alternate embodiment, two cameras may be mounted on separate tripods using gimbal systems to pivot the cameras about the lens nodal points in an appropriate manner. By pointing and tilting the cameras using standard leveling techniques prior to the start of the image acquisition process, a camera plane is established which serves as the baseplane for recording camera pointing data.

Although the invention has been described herein with reference to specific embodiments, many modifications and variations therein will readily occur to those skilled in the art. Accordingly, all such variations are included within the intended scope of the invention.

Claims

1. A method of acquiring an image mosaic suitable for photogrammetric analysis comprising the steps of:

providing at least one camera having an objective lens for focusing light from a scene onto an image plane, and

moving the camera to different orientations with respect to the scene to produce a series of still-frame images of the scene wherein the center of camera motion is coincident with the principal node of the camera lens, thereby minimizing image distortion.

2. A method of acquiring an image mosaic suitable for photogrammetric analysis according to claim 1 wherein the camera is mounted on a motorized rotational stage.

3. A method of acquiring an image mosaic suitable for photogrammetric analysis according to claim 2 including the step of controlling camera motion by an indexing head assembly directed by a system controller.

4. A method of acquiring an image mosaic suitable for photogrammetric analysis according to claim 3 wherein the system controller comprises a microprocessor, an image frame grabber, a storage device, and an indexing head controller, and including the steps of simultaneously obtaining and temporarily storing images from the camera by the frame grabber and the storage device in response to signals from the microprocessor.

5. A method of acquiring an image mosaic suitable for photogrammetric analysis according to claim 3 including the step of controlling the camera exposure by directing movement of the shutter in response to signals from the system controller.

6. Stereoscopic imaging apparatus comprising:

at least one camera having an objective lens for focusing light from a scene onto an image plane; and

means for controlling motion of the camera about the principal node of the objective lens.

7. Stereoscopic imaging apparatus according to claim 6 further comprising an indexing head assembly for controlling the means for controlling motion of the camera about the principal node of said camera lens.

8. Stereoscopic imaging apparatus according to claim 7 further comprising system control means for controlling the indexing head assembly.

9. Stereoscopic imaging apparatus according to claim 8 wherein the system control means comprises a microprocessor, image frame grabber means, digital storage means, and indexing head control means and wherein the indexing head control means directs the indexing head assembly to control motion of the camera, the frame grabber means simultaneously obtains and temporarily stores images from the camera and thereafter transmits the images to the digital storage means.

10. Stereoscopic imaging apparatus comprising camera support means, a pair of cameras supported in

spaced relation by the camera support means, each of the cameras having a lens with a nodal point, and camera position control means for each of the cameras arranged to impart angular motion to the cameras about the nodal points of the lenses.

11. Stereoscopic imaging apparatus comprising camera support means, a pair of cameras mounted on separate camera support means, each of the cameras having a lens with a nodal point, and common camera position control means for each of the cameras arranged to impart angular motion to the cameras about the nodal points of the lenses.

12. Stereoscopic imaging apparatus comprising camera support means, a camera having a lens with a nodal point supported by the camera support means, and camera position control means arranged to impart angular motion to the camera about the nodal point of the lens.

13. Stereoscopic imaging apparatus according to claim 10, 11 or 12 including position control means for the camera support means arranged to impart motion to the camera support means about an axis extending through the nodal point of both camera lenses.

14. Stereoscopic imaging apparatus according to claim 13 wherein the position control means for the camera support means is also arranged to impart motion to the camera support means about an axis perpendicular to the axis extended through the nodal points.

15. Stereoscopic imaging apparatus according to claim 10, 11 or 12 including control means comprising microprocessor means for controlling the camera position control means and operation of the camera and camera image storage means for storing images obtained by the camera and supplied to the control means.

16. Stereoscopic imaging apparatus according to claim 15 including display means for displaying images obtained by the camera means.

17. Stereoscopic imaging apparatus according to claim 15 wherein the control means controls the operation of the camera to produce a mosaic of stereoscopic images of a scene.

18. Stereoscopic imaging apparatus according to claim 15 wherein the control means controls the operation of the camera to obtain successive images of a scene at different exposures in accordance with an image intensity histogram.

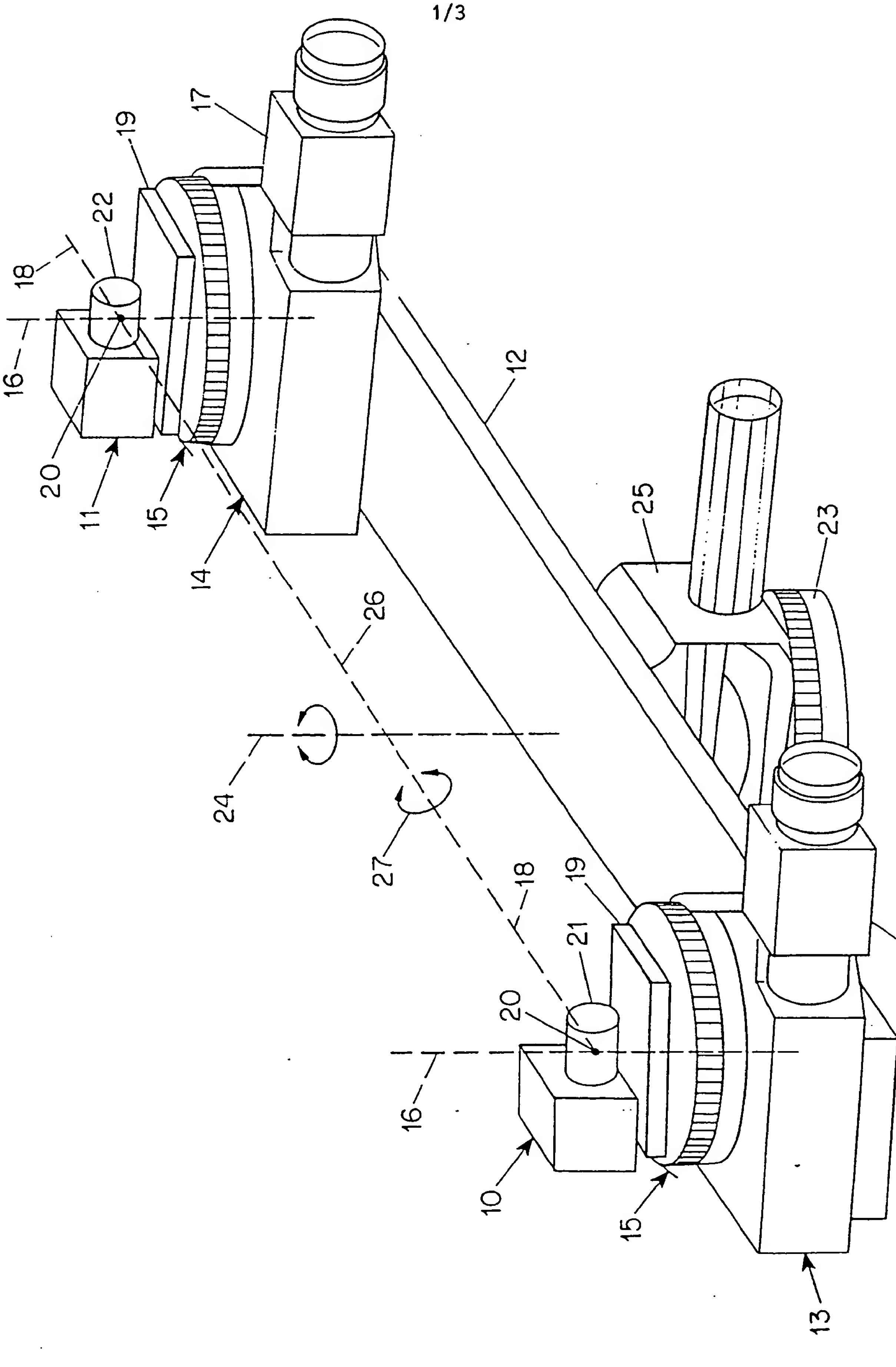

FIG. 1

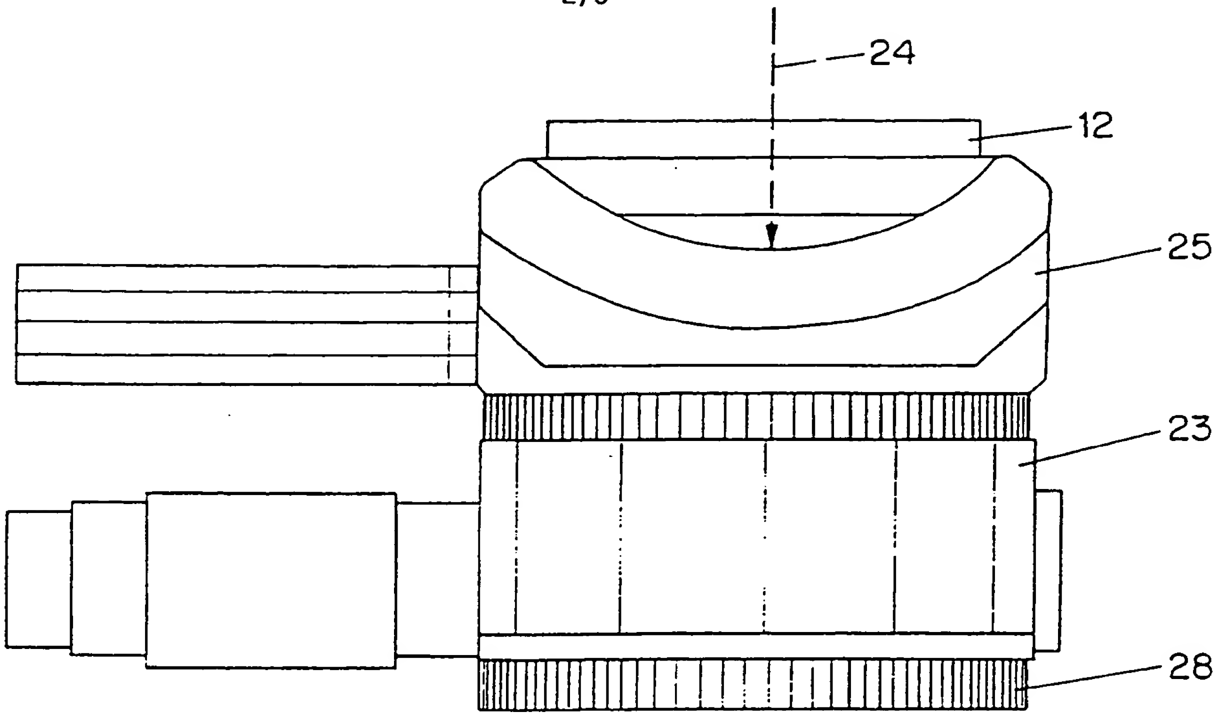
24
12
25
23
28

FIG. 2

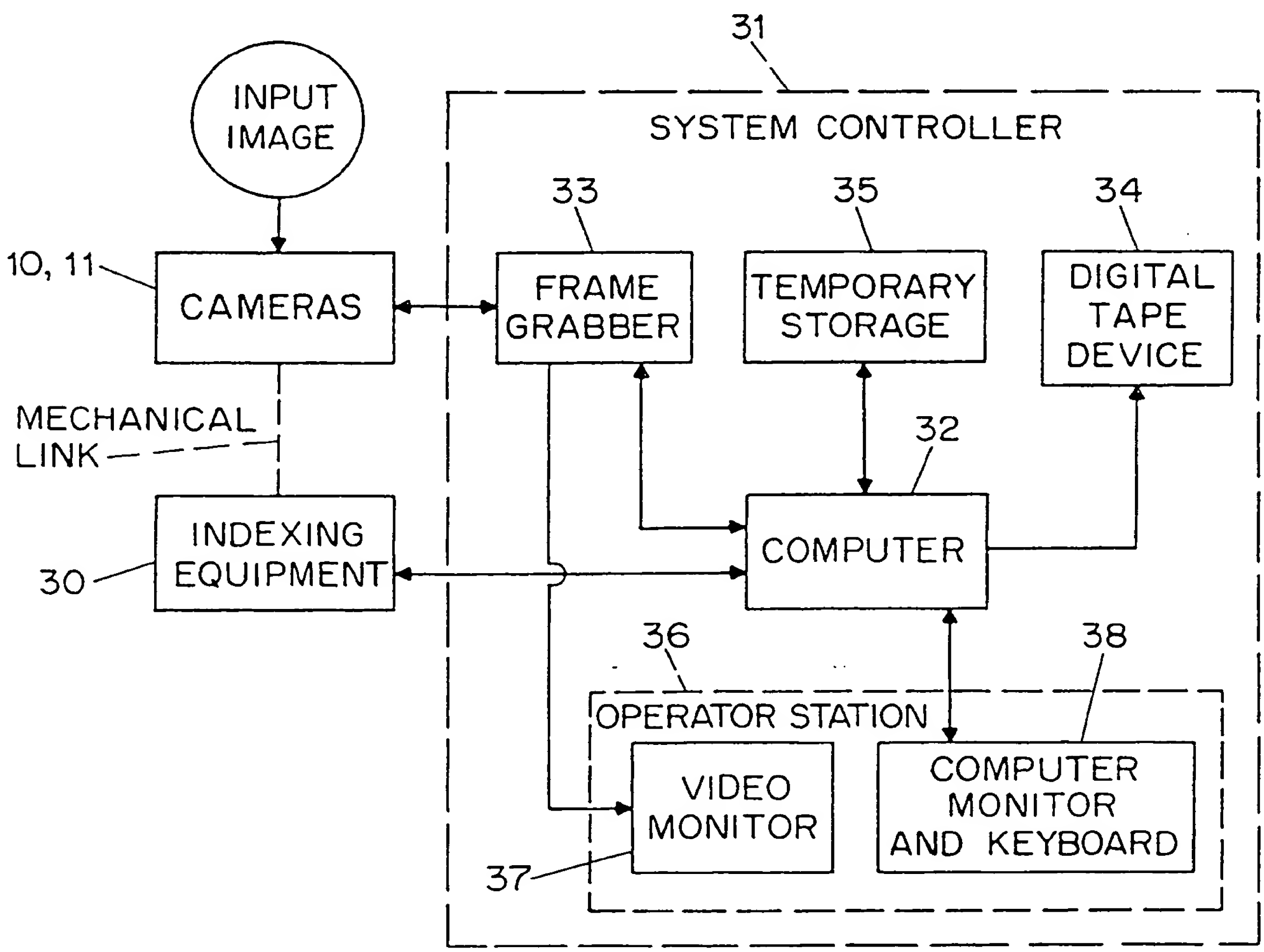
31
SYSTEM CONTROLLER
INPUT IMAGE
10, 11
CAMERAS
33
FRAME GRABBER
35
TEMPORARY STORAGE
34
DIGITAL TAPE DEVICE
MECHANICAL LINK
32
COMPUTER
30
INDEXING EQUIPMENT
36
38
OPERATOR STATION
VIDEO MONITOR
COMPUTER MONITOR AND KEYBOARD
37

FIG. 3

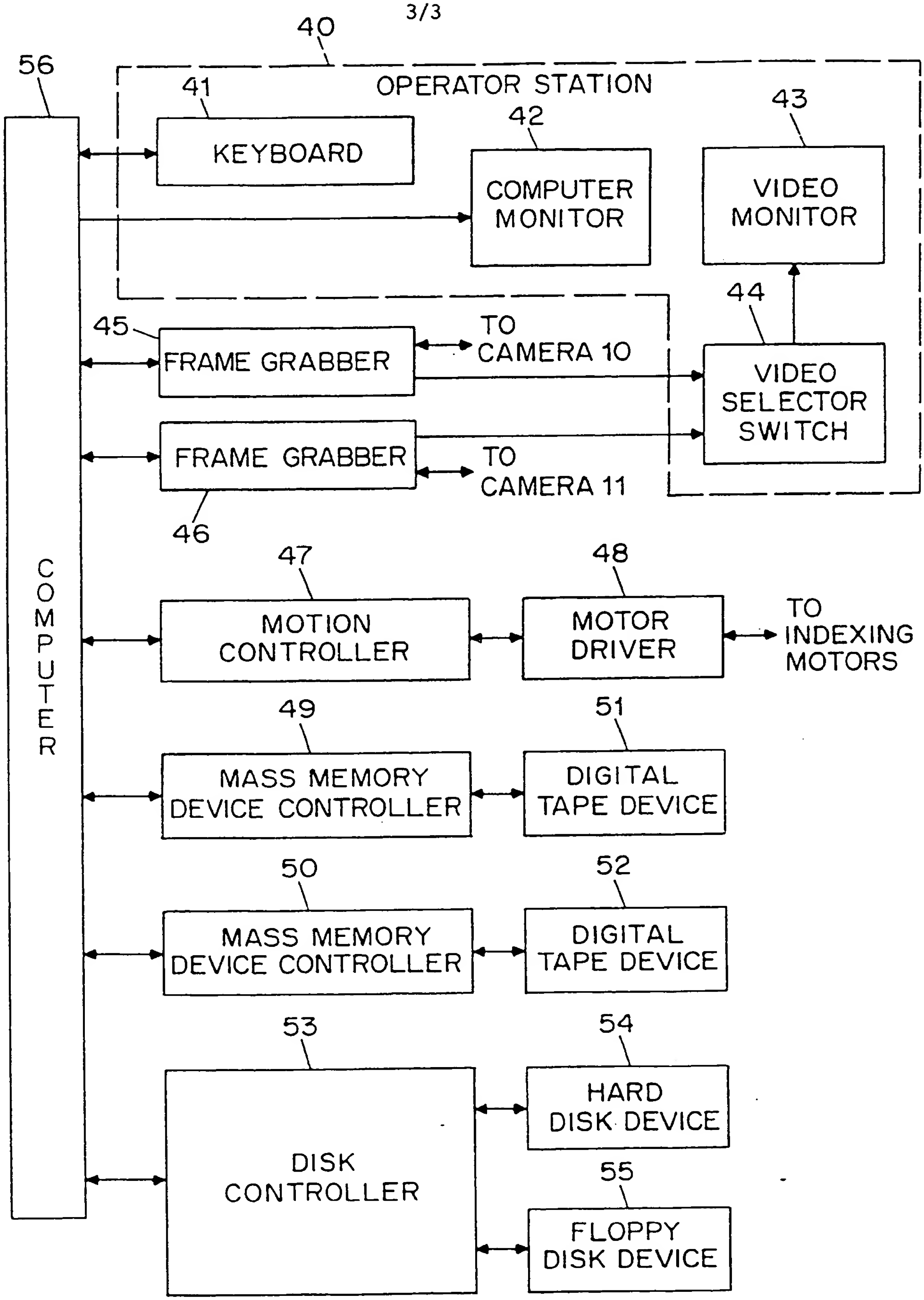
40
56
OPERATOR STATION
41
KEYBOARD
42
COMPUTER MONITOR
43
VIDEO MONITOR
44
45
FRAME GRABBER
TO CAMERA 10
VIDEO SELECTOR SWITCH
FRAME GRABBER
TO CAMERA 11
46
COMPUTER
47
MOTION CONTROLLER
48
MOTOR DRIVER
TO INDEXING MOTORS
49
MASS MEMORY DEVICE CONTROLLER
51
DIGITAL TAPE DEVICE
50
MASS MEMORY DEVICE CONTROLLER
52
DIGITAL TAPE DEVICE
53
DISK CONTROLLER
54
HARD DISK DEVICE
55
FLOPPY DISK DEVICE

FIG. 4

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G03B35/08 H04N13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 494 752 (ZANDAR RESEARCH LTD.) 15 July 1992 see column 1 - column 10; figure 1	1
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 117 (E-731)22 March 1989 & JP,A,63 288 577 (SHARP CORP.) 25 November 1988 see abstract	1
A	EP,A,0 307 283 (THOMSON -CSF) 15 March 1989 see column 2 - column 5; figures 1-5	1-5
Y	see column 2 - column 5; figures 1-5	6,7,9

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 March 1994	11.03.94

Name and mailing address of the ISA	Authorized officer
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International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,5 065 236 (D.B.DINER) 12 November 1991 see column 2 - column 16; figures 1-10	1-5
Y	see column 2 - column 16; figures 1-10	6-10,15, 16
A	GB,A,2 168 565 (M.ROBINSON) 18 June 1986 see page 2 - page 3; figures 1-5	1-5
Y	see page 2 - page 3; figures 1-5	6-10,15, 16
A	EP,A,0 146 476 (THOMSON-CSF) 26 June 1985 see page 3 - page 10; figure 1	1-5
Y	see page 3 - page 10; figure 1	6-10,15, 16

1

Information on patent family members

International Application No
PCT/US 93/10107

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